US 20170319048A1

(19) United States

(12) Patent Application Publication

IKEDA

(10) Pub. No.: US 2017/0319048 A1

(43) Pub. Date: Nov. 9, 2017

(54) FLEXIBLE TUBE INSERTION APPARATUS

(71) Applicant: OLYMPUS CORPORATION, Tokyo (JP)

(72) Inventor: Yuichi IKEDA, Tama-shi (JP)

(73) Assignee: OLYMPUS CORPORATION, Tokyo (JP)

(21) Appl. No.: 15/660,084

(22) Filed: Jul. 26, 2017

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2015/052387, filed on Jan. 28, 2015.

Publication Classification

(51) Int. Cl.

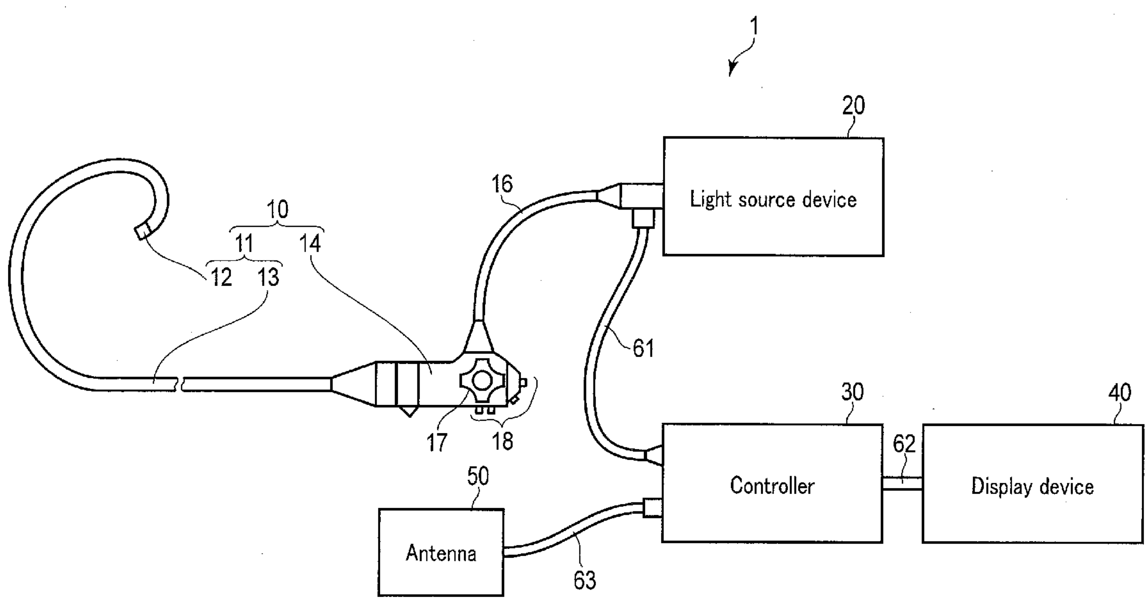
A61B 1/005 (2006.01)
A61B 1/00 (2006.01)
A61B 1/01 (2006.01)
A61B 1/00 (2006.01)
G02B 23/24 (2006.01)

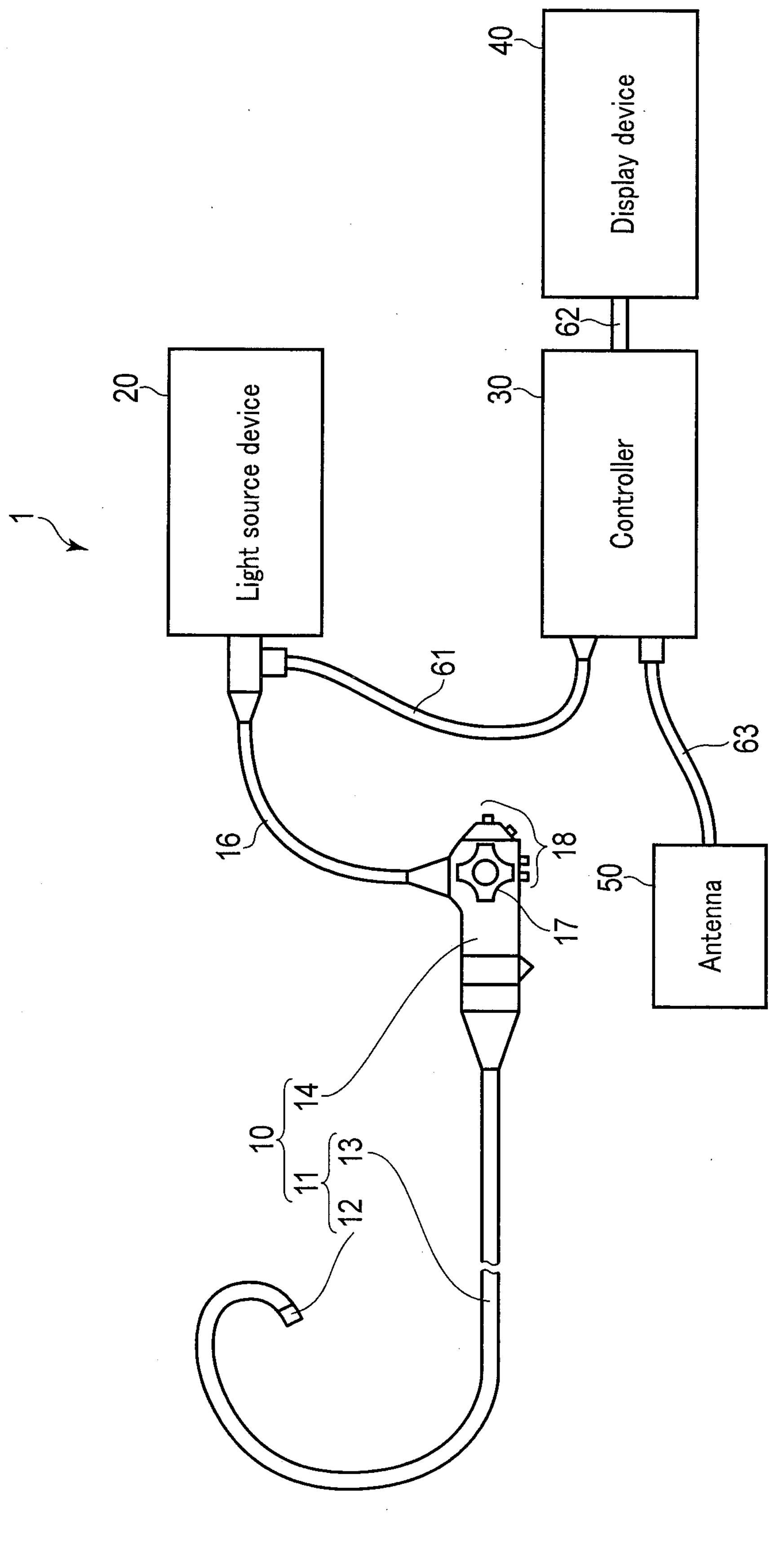
(52) U.S. Cl.

CPC *A61B 1/0055* (2013.01); *A61B 1/01* (2013.01); *A61B 1/00071* (2013.01); *A61B 1/00154* (2013.01); *G02B 23/2476* (2013.01)

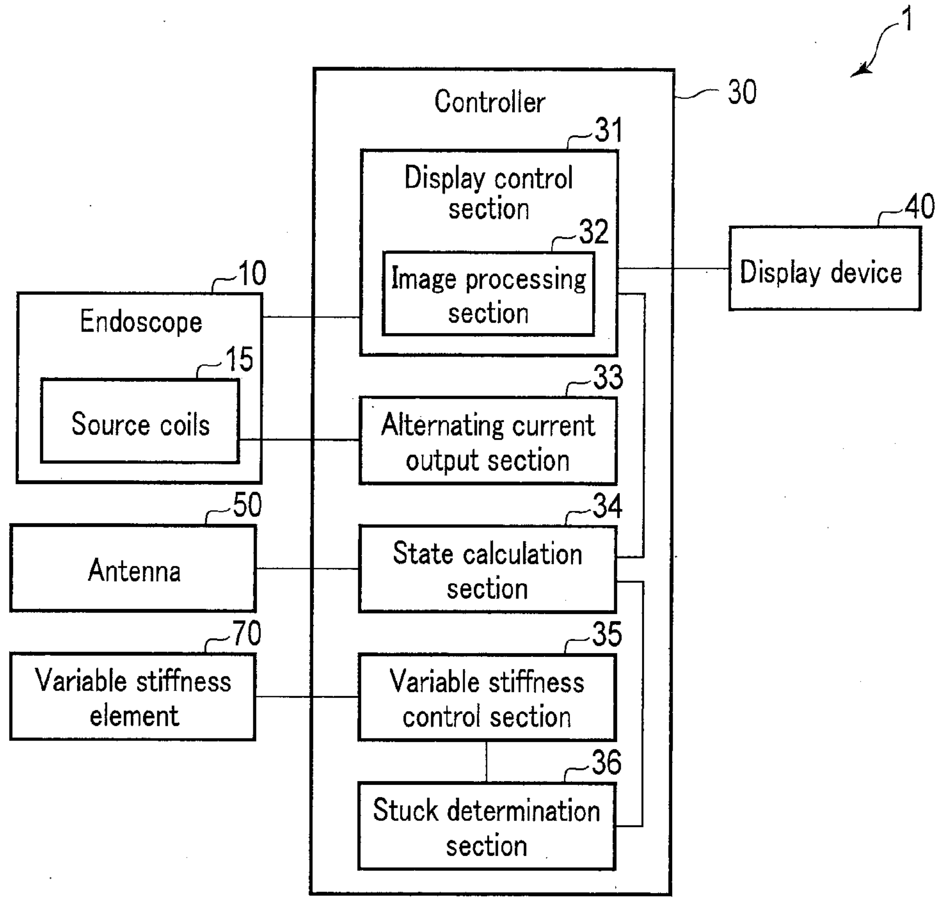
(57) ABSTRACT

A flexible tube insertion apparatus includes a tubular insertion section, a variable stiffness section that causes change of bending stiffness of the insertion section, in regard to continuous segments defined in an axial direction of the insertion section, on a segment-by-segment basis, and a stiffness connecting portion. The stiffness connecting portion is arranged across at least a pair of adjacent segments of the segments. The stiffness connecting portion causes change of bending stiffness of a portion between the pair of segments in such a manner that the bending stiffness of the portion between the pair of segments is continuous with bending stiffness of the pair of segments, in accordance with change of the bending stiffness of the portion between the pair of segments by the variable stiffness section.

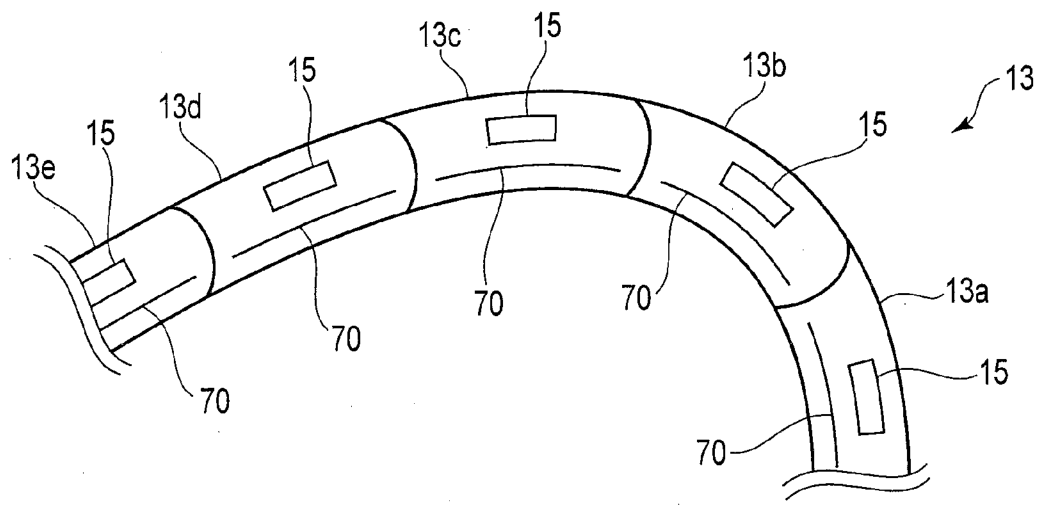



1
20
Light source device
30
Controller
40
Display device
50
Antenna
61
62
63
16
17
18
10
11
12
13
14

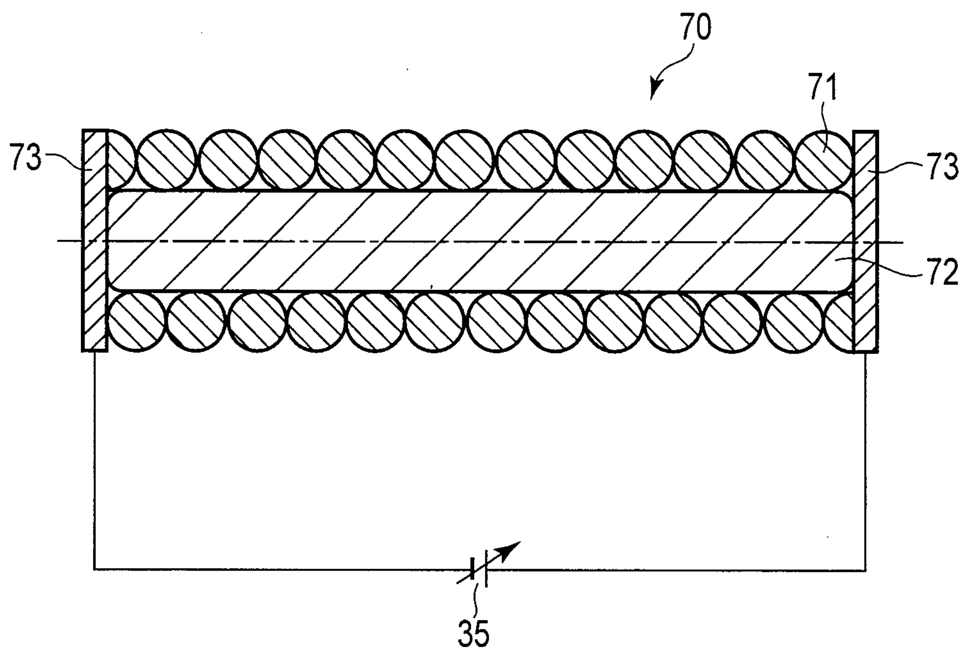
F I G. 1


1
Controller
30
31
Display control section
32
Image processing section
40
Display device
10
Endoscope
15
Source coils
33
Alternating current output section
50
Antenna
34
State calculation section
70
Variable stiffness element
35
Variable stiffness control section
36
Stuck determination section

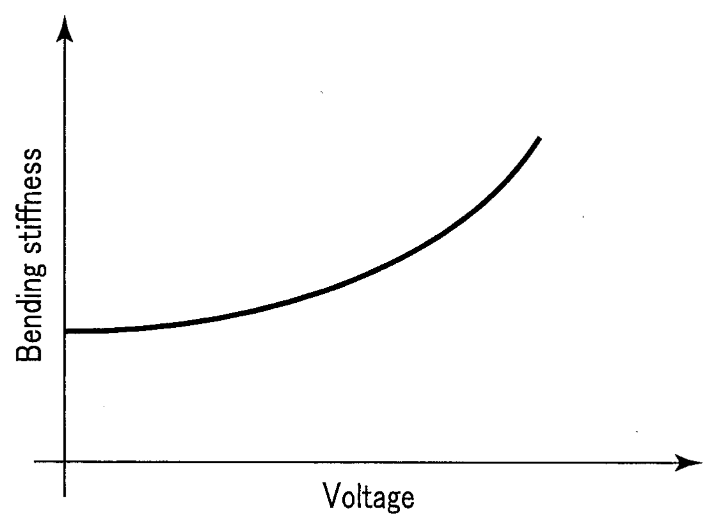
F I G. 2


13c
15
13b
13
15
13d
15
13e
15
70
70
70
13a
70
15
70
70

F I G. 3



F I G. 4



F I G. 5

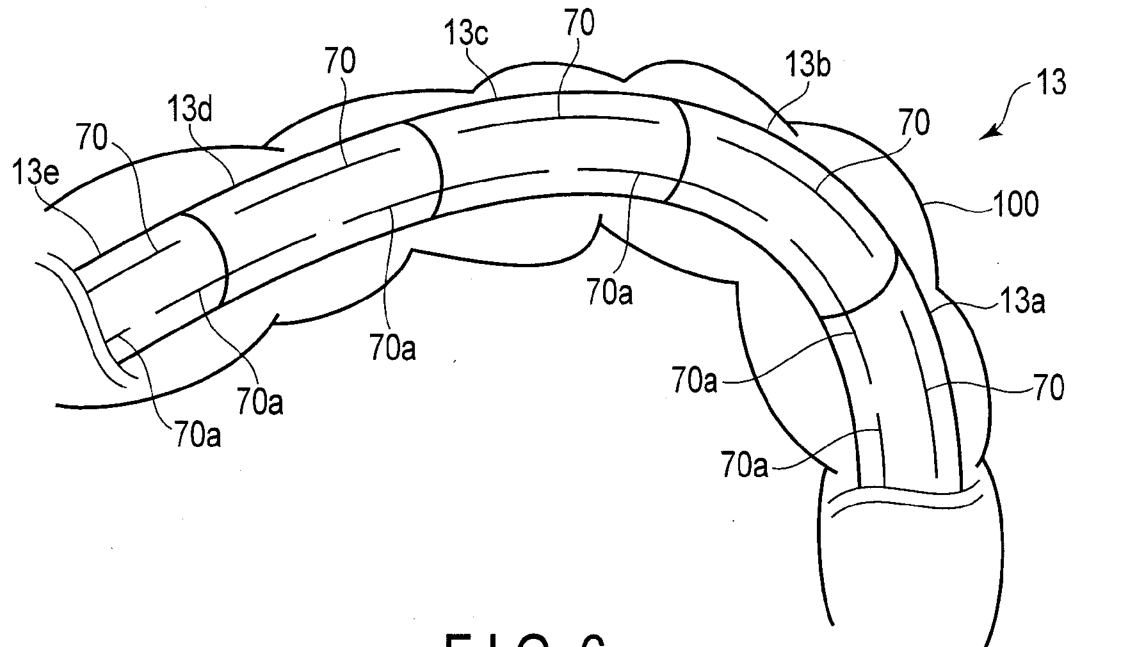

13c
70
13b
13
70
13d
70
70
13e
100
70a
13a
70a
70a
70
70a
70a
70a

FIG. 6

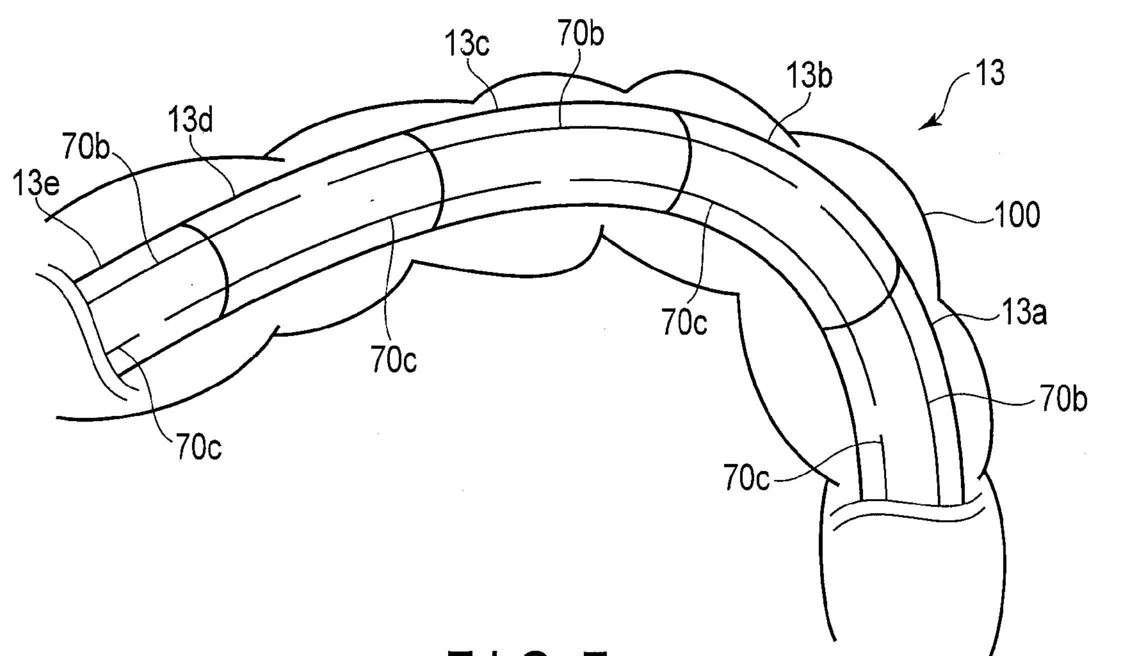
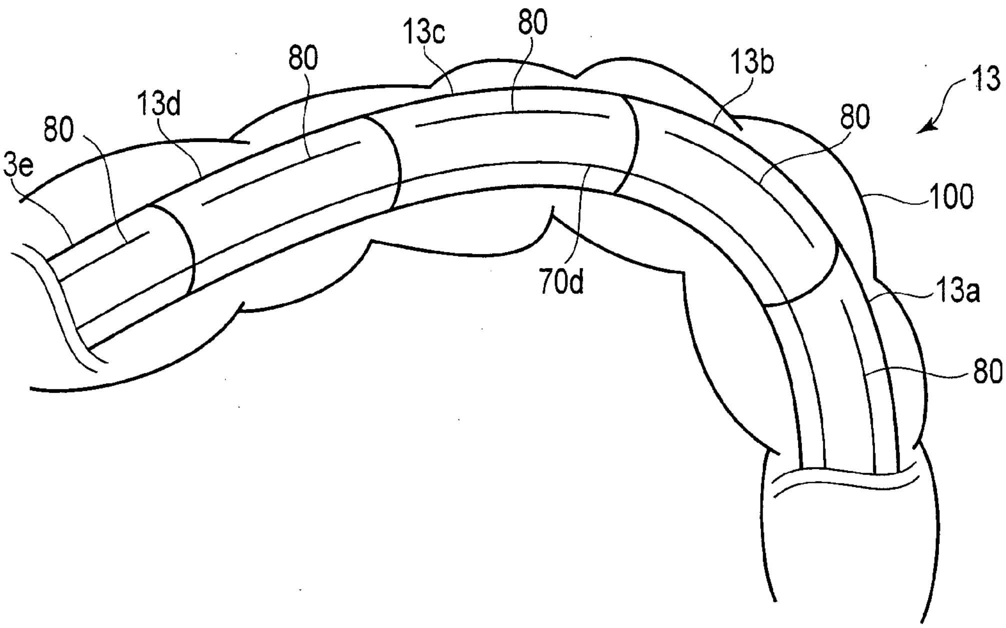
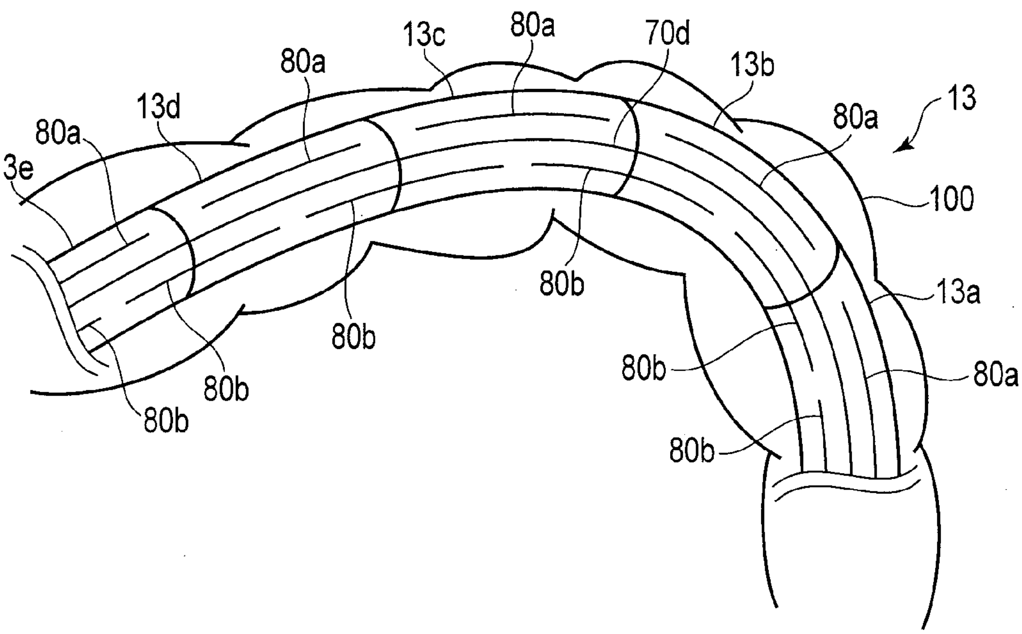

13c
70b
13b
13
13d
70b
13e
100
13a
70c
70c
70b
70c
70c

FIG. 7


13c
80
80
13b
13
13d
80
80
13e
100
70d
13a
80

F I G. 8


13c
80a
70d
80a
13b
13
13d
80a
80a
13e
100
80b
80b
13a
80b
80a
80b
80b
80b

F I G. 9

FLEXIBLE TUBE INSERTION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation application of PCT Application No. PCT/JP2015/052387, filed Jan. 28, 2015, the entire contents of all of which are incorporated herein by references.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a flexible tube insertion apparatus comprising an insertion section to be inserted into a subject.

2. Description of the Related Art

[0003] It is known that a flexible tube insertion apparatus such as an endoscope apparatus comprising a flexible, elongated insertion section provides improved ease of insertion into a winding part of a subject's body by providing the insertion section with a variable stiffness mechanism. For example, Japanese Patent No. 3752328 discloses an endoscope apparatus comprising an insertion section divided into a plurality of segments as viewed in the longitudinal direction, with a shape-memory alloy actuator arranged in each segment as a variable stiffness mechanism. Each segment is provided with a pressure sensor. In the endoscope apparatus, when the insertion section is inserted into a subject (e.g., the large intestine) and some segment of the insertion section is pressed from outside (e.g., by the intestinal wall), the pressure sensor of that segment senses the pressing and actuates the shape-memory alloy actuator of that segment to decrease the stiffness of that segment.

BRIEF SUMMARY OF THE INVENTION

[0004] One embodiment of the present invention is a flexible tube insertion apparatus comprising a tubular insertion section to be inserted into a subject, a variable stiffness section that causes change of bending stiffness of the insertion section, in regard to a plurality of continuous segments defined in an axial direction of the insertion section, on a segment-by-segment basis, and a stiffness connecting portion that is arranged across at least a pair of adjacent segments of the plurality of segments, and causes change of bending stiffness of a portion between the pair of segments in such a manner that the bending stiffness of the portion between the pair of segments is continuous with bending stiffness of the pair of segments, in accordance with change of the bending stiffness of the portion between the pair of segments by the variable stiffness section.

[0005] Advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0006] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0007] FIG. **1** is a diagram schematically showing a configuration of an endoscope apparatus.

[0008] FIG. **2** is a block diagram schematically showing a main configuration of the endoscope apparatus.

[0009] FIG. **3** is a diagram schematically showing an exemplary configuration of a flexible tube portion.

[0010] FIG. **4** is a diagram schematically showing a configuration of a variable stiffness element.

[0011] FIG. **5** is a diagram showing a voltage-bending stiffness characteristic of the variable stiffness element.

[0012] FIG. **6** is a diagram schematically showing an exemplary configuration of the flexible tube portion according to a first embodiment.

[0013] FIG. **7** is a diagram schematically showing another exemplary configuration of the flexible tube portion according to the first embodiment.

[0014] FIG. **8** is a diagram schematically showing an exemplary configuration of a flexible tube portion according to a second embodiment.

[0015] FIG. **9** is a diagram schematically showing another exemplary configuration of the flexible tube portion according to the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0016] FIG. **1** is a diagram schematically showing a configuration of an endoscope apparatus **1**, which is a flexible tube insertion apparatus. FIG. **2** is a block diagram schematically showing a main configuration of the endoscope apparatus **1**. The endoscope apparatus **1** comprises an endoscope **10**, a light source device **20**, a controller **30**, a display device **40**, and an antenna **50**.

[0017] The endoscope **10** includes a tubular, elongated insertion section **11** to be inserted into a subject, and an operation section **14** provided on the proximal side of the insertion section **11**. The endoscope **10** is, for example, a colonoscope. The insertion section **11** includes a distal rigid portion **12** and a flexible tube portion **13** provided on the proximal side of the distal rigid portion **12**. The distal rigid portion **12** incorporates, for example, an illumination optical system (illumination window), an observation optical system (observation window), and an image sensor, not shown in the drawings. The flexible tube portion **13** is a flexible, elongated portion, and comprises a plurality of segments, which will be described later. The flexible tube portion **13** is provided with a plurality of source coils **15** used for detection of the state (bending shape, distortion, etc.) of the flexible tube portion **13** (see FIG. **3**). The operation section **14** is provided with, for example, an angle knob **17** and switches **18**, used for various operations including a bending operation and an imaging operation of the endoscope **10**. A distal end of the flexible tube portion **13** may be bent in any direction by an operation of the angle knob **17**.

[0018] The light source device **20** is connected to the endoscope **10** via a universal cord **16**, which extends from the proximal side of the operation section **14** of the endoscope **10**. The universal cord **16** includes, for example, a light guide (optical fiber) connected to the illumination optical system, and an electric cable connected to the image sensor. The light source device **20** supplies light to be emitted from the illumination window of the distal rigid portion **12** via the light guide.

[0019] The controller **30** is formed of a device including a processor like CPU or the like, or hardware circuitry like ASIC (Application Specific Integrated circuit), FPGA (Field Programmable Gate Array) or the like. As shown in FIG. **2**, the controller **30** includes a display control section **31** (a display control circuit **31**) including an image processing section **32** (an image processing circuit **32**), an alternating current (AC) signal output section **33** (an AC signal output circuit **33**), a state calculation section **34** (a state calculation circuit **34**), a variable stiffness control section **35** (a variable stiffness control circuit **35**), and a stuck determination section **36** (a stuck determination section **36**). The display control section **31** is connected to the electric cable in the universal cord **16** via a cable **61**, and thus connected to the endoscope **10** (the image sensor of the distal rigid portion **12**). The display control section **31** is also connected to the display device **40** via a cable **62**. The AC signal output section **33** is connected to the source coils **15** via a cable, not shown. The state calculation section **34** is connected to the antenna **50** via a cable **63**. The variable stiffness control section **35** is connected to a variable stiffness element **70**, which will be described later, via a cable, not shown.

[0020] The antenna **50** is arranged around the periphery of the subject into which the endoscope **10** is to be inserted. The antenna **50** detects a magnetic field generated by the source coils **15** provided in the flexible tube portion **13**. The antenna **50** outputs a detection signal to the controller **30** (state calculation section **34**) via the cable **63**.

[0021] With reference to FIG. **3**, the configuration of the flexible tube portion **13** will be further described. FIG. **3** is a diagram schematically showing an exemplary configuration of the flexible tube portion **13**. In the flexible tube portion **13**, a plurality of source coils **15** are spaced in the longitudinal direction (axial direction) of the insertion section **11**, as magnetic field generating elements that generate a magnetic field. The source coils **15** are formed by winding a conducting wire around a magnetic body formed of ferrite, permalloy, or the like. For convenience, let us assume that the flexible tube portion **13** comprises a plurality of segments (virtual units into which the flexible tube portion **13** is evenly divided as viewed in the longitudinal direction) defined in the axial direction thereof. In the example of FIG. **3**, five segments **13***a*, **13***b*, **13***c*, **13***d*, and **13***e* of the flexible tube portion **13** are shown, and the source coil **15** is arranged in each segment. The source coil **15** provided in each segment is arranged so as to allow the antenna **50** and the controller **30** (state calculation section **34**) to detect the state of each segment based on the generated magnetic field. The arrangement of the source coil **15** is not limited thereto, and the source coil **15** may be arranged in only some of the segments.

[0022] A plurality of variable stiffness elements (variable stiffness actuators) **70** are provided in the flexible tube portion **13**. The variable stiffness elements **70** are variable stiffness sections that change the bending stiffness of the flexible tube portion **13** on a segment-by-segment basis in regard to the segments in which the variable stiffness elements **70** are provided. FIG. **4** is a diagram schematically showing a configuration of the variable stiffness element **70**. The variable stiffness element **70** includes a coil pipe **71** formed of a metal wire, an electroactive polymer artificial muscle (EPAM) **72** sealed in the coil pipe **71**, and electrodes **73** provided on both ends of the coil pipe **71**. As shown in FIG. **2**, the variable stiffness element **70** is connected to the variable stiffness control section **35**, and a voltage may be applied from the variable stiffness control section **35** to the EPAM **72** in the coil pipe **71** via the electrodes **73**. The EPAM **72** is an actuator that changes its stiffness and extends and contracts when a voltage is applied. The variable stiffness element **70** is incorporated into the flexible tube portion **13** in such a manner that the central axis of the coil pipe **71** coincides with or is parallel to the central axis of the flexible tube portion **13**. The variable stiffness element **70** (EPAM **72**) has a stiffness greater than the stiffness of the members forming the flexible tube portion **13**.

[0023] The electrode **73** (EPAM **72**) of the variable stiffness element **70** is applied with a voltage from the variable stiffness control section **35** via a cable, not shown. When such a voltage is applied, the EPAM **73** tends to expand its diameter with the central axis of the coil pipe **71** at its center. However, the EPAM **73** is surrounded by the coil pipe **71**, and is restrained from expanding its diameter. Accordingly, the bending stiffness of the variable stiffness element **70** increases as the value of the applied voltage increases, as shown in FIG. **5**. That is, when the stiffness of the variable stiffness element **70** is changed, the bending stiffness of the flexible tube portion **13** incorporating the variable stiffness element **70** also changes.

[0024] Next, the operation of the endoscope apparatus **1** will be described.

[0025] The insertion section **11** of the endoscope **10** is inserted by a user into a subject (from the anus through the rectum into the colon (intestinal tract)). In this case, the insertion section **11** passes through the subject while bending to follow the shape inside of the subject's body. The display control section **31** of the controller **30** obtains an imaging signal output from the image sensor of the distal rigid portion **12** of the insertion section **11** via the electric cable or the like of the universal cord **16**. The display control section **31** causes the image processing section **32** to generate an image of the interior of the subject based on the obtained imaging signal. The display control section **31** controls the operation of the display device **40** via the cable **62**, and causes the display device **40** to display the generated image.

[0026] During insertion, the AC signal output section **33** sequentially applies an AC signal to the source coils **15** via the cable **61** or the like. Each of the source coils **15** generates a magnetic field around the periphery thereof. That is, information regarding the position of the source coil **15** is output from the source coil **15**. The antenna **50** detects the position of the source coil **15** based on the output of the source coil **15**, and outputs a detection signal to the state calculation section **34**. The state calculation section **34** estimates a state (e.g., a three-dimensional shape) of the flexible tube portion **13** (insertion section **11**) based on the detection signal from the antenna **50**. The information on the estimated state is transmitted to the display control section **31**, and a computer graphics image corresponding to the estimated state is generated. The display control section **31** causes the display device **40** to display the generated image. The state calculation section **34** calculates a state quantity (e.g., a bending angle of each segment) indicating the state of each segment, based on the estimated state of the flexible tube portion **13**.

[0027] The stuck determination section **36** obtains the state quantity of each segment calculated by the state calculation section **34**. The stuck determination section **36** determines, from the obtained state quantity, whether or not each segment is stuck (i.e., whether smooth insertion (passage) of the flexible tube portion **13** is prevented by the segment being bent into a V shape). If any of the segments are determined to be stuck, a control signal is transmitted from the stuck determination section **36** to the variable stiffness control section **35**, and the stiffness of the variable stiffness element **70** provided in that segment is decreased. This makes that segment soft, eliminating the V-shaped bend. As a result, further insertion into a deep portion of the large intestine is made easy.

[0028] The determination by the stuck determination section **36** may be constantly performed in real time during insertion, or may be manually performed by a user by making an input to an input device, not shown, when the patient feels pain that results from pressure on the intestinal wall during insertion.

[0029] The stuck determination section **36** may determine whether any of the segments is substantially linear from the obtained state quantity, and transmit, to the variable stiffness control section **35**, a control signal to increase the stiffness of the variable stiffness element **70** provided in the substantially linear segment. This prevents the flexible tube portion **13** from being bent at the substantially linear portion, and striking against the intestinal wall, increasing the ease of insertion.

[0030] Thus, according to the endoscope apparatus **1**, the variable stiffness elements **70** are driven according to the state of the flexible tube portion **13** in the subject, in such a manner that the bending stiffness of the insertion section **11** (flexible tube portion **13**) is changed on a segment-by-segment basis, to allow smooth insertion of the flexible tube portion **13** into a deep portion of the winding large intestine.

First Embodiment

[0031] The first embodiment of the present invention will be described with reference to FIGS. **6** and **7**.

[0032] FIG. **6** is a diagram schematically showing an exemplary configuration of a flexible tube portion **13** according to the first embodiment. In FIG. **6** and the subsequent drawings, the flexible tube portion **13** is shown in a state of being inserted into a large intestine **100**, and the source coils **15** are omitted. In FIG. **6**, in addition to the variable stiffness element **70** provided in each of the segments **13**_a_, **13**_b_, **13**_c_, **13**_d_, and **13**_e_ of the flexible tube portion **13**, a variable stiffness element **70**_a_ arranged across two continuous (adjacent) segments (for example, segments **13**_a_ and **13**_b_, segments **13**_b_ and **13**_c_, segments **13**_c_ and **13**_d_, and segments **13**_d_ and **13**_e_) is provided. The variable stiffness element **70**_a_ is a stiffness connecting portion arranged at a connecting portion between the segments, and designed to cause change of bending stiffness of a portion between the segments in such a manner that the bending stiffness of the portion between the segments is continuous with the bending stiffness of the segments (the bending stiffness of the portion between the segments does not abruptly change). The configuration and operating principle of the variable stiffness element **70**_a_ are similar to those of the variable stiffness element **70**. The length of the variable stiffness element **70** in the longitudinal direction is less than the length of the segment, and the length of the variable stiffness element **70**_a_ in the longitudinal direction is greater than a distance between the variable stiffness elements **70** provided in the adjacent segments.

[0033] The variable stiffness element **70** is not arranged at the connecting portion (boundary) between the segments, but the variable stiffness element **70**_a_ is arranged at least in the connecting portion between the segments. In other words, the variable stiffness elements are arranged without interruption in the longitudinal direction of the flexible tube portion **13**. In FIG. **6**, for example, the variable stiffness elements **70**_a_ are arranged in all areas where the variable stiffness elements **70** are not arranged in the longitudinal direction of the flexible tube portion **13**, and are arranged so as to partially overlap the variable stiffness elements **70** in the longitudinal direction.

[0034] FIG. **7** is a diagram schematically showing another exemplary configuration of the flexible tube portion **13** according to the first embodiment. In FIG. **7**, a variable stiffness element **70**_b_ arranged across three continuous segments (for example, segments **13**_b_, **13**_c_, and **13**_d_) and a variable stiffness element **70**_c_ arranged across three continuous segments different therefrom (for example, segments **13**_a_, **13**_b_, and **13**_c_, and segments **13**_c_, **13**_d_, and **13**_e_) are provided. The variable stiffness elements **70**_b_ and **70**_c_ are stiffness connecting portions arranged so as to overlap each other at the connecting portion between the segments, and cause change of the bending stiffness of the portion between the segments in such a manner that the bending stiffness of the portion between the segments is continuous with the bending stiffness of the segments. The configuration and the operating principle of the variable stiffness elements **70**_b_ and **70**_c_ are similar to those of the variable stiffness elements **70**. The variable stiffness elements **70**_b_ and **70**_c_ are alternately arranged, and are arranged without interruption in the longitudinal direction of the flexible tube portion **13**. In FIG. **7**, the longitudinal lengths of the variable stiffness elements **70**_b_ and **70**_c_ are the same, but are not limited thereto. It is only required that the variable stiffness elements **70**_c_ are arranged in all areas where the variable stiffness elements **70**_b_ are not arranged in the longitudinal direction of the flexible tube portion **13**.

[0035] For example, when only the variable stiffness elements **70** having a length less than the length of the segment is arranged in each segment, as shown in FIG. **3**, the variable stiffness element is absent in the connecting portion between the segments of the insertion section **11**. Accordingly, when the variable stiffness control section **35** transmits, to the variable stiffness elements **70** of two adjacent segments, a control signal to increase the stiffness thereof, the connecting portion between the two segments remains soft. Thus, when such a soft connecting portion contacts the intestinal wall or the like and is applied with an external force (reaction), the connecting portion between the segments may become a stiffness-discontinuous portion (a boundary of stiffness occurs) and the flexible tube portion **13** may be bent into a V shape, reducing the ease of insertion. In addition, when the bent flexible tube portion **13** strikes and presses against the intestinal wall, the patient suffers considerable distress.

[0036] In the present embodiment, the variable stiffness elements (stiffness connecting portions) are arranged without space even at the connecting portion between the segments in the longitudinal direction of the flexible tube portion **13**, and allow the bending stiffness of the flexible tube portion **13** to be adjusted at the boundary between the segments. In the example of FIG. **6**, when the stiffness of two adjacent segments is increased, the stiffness of not only the variable stiffness elements **70** of the adjacent two segments, but also that of the variable stiffness element **70***a* arranged across these segments is similarly increased. Thus, V-shaped bending or buckling does not occur at the boundary between the segments when an external force is applied from the intestinal wall or the like.

[0037] Since the variable stiffness elements are thus arranged at the boundary between the segments, a boundary of stiffness does not occur at the connecting portion between the segments, and the bending stiffness is free from discontinuity in the longitudinal direction of the flexible tube portion **13**. It is thus possible to provide a flexible tube insertion apparatus that does not cause V-shaped bending at a boundary between the segments when an external force is applied, improving ease of insertion and ease of operation.

[0038] Furthermore, according to the present embodiment, during insertion into, for example, the large intestine, it is also possible to reduce the load on the intestinal tract caused by bending of the flexible tube portion **13** at the flexures of the large intestine, including the rectosigmoid flexure, the left colic flexure, and the right colic flexure, thus improving ease of insertion and reducing the patient's distress.

[0039] The arrangement and longitudinal length of the variable stiffness elements shown in FIGS. **6** and **7** are shown by way of example, and may be any other arrangement and length if the variable stiffness elements are arranged without interruption in the longitudinal direction of the flexible tube portion **13**.

Second Embodiment

[0040] The second embodiment of the present invention will be described with reference to FIGS. **8** and **9**.

[0041] FIG. **8** is a diagram schematically showing an exemplary configuration of a flexible tube portion **13** according to the second embodiment. In FIG. **8**, a long variable stiffness element **70***d* is arranged as a variable stiffness section in segments **13***a*, **13***b*, **13***c*, **13***d*, and **13***e* of the flexible tube portion **13**. The configuration of the variable stiffness element **70***d* is similar to that of the variable stiffness elements **70**. The variable stiffness element **70***d* is one continuous member extending from the segment **13***a* to the segment **13***e*, and the variable stiffness element **70** itself also functions as a stiffness connecting portion arranged across a plurality of boundaries between the segments. That is, according to the present embodiment, the variable stiffness element **70***d* causes change of the bending stiffness of a portion between the segments in such a manner that the bending stiffness of the portion between the segments is continuous with the bending stiffness of the segments.

[0042] Each of the segments **13***a*, **13***b*, **13***c*, **13***d*, and **13***e* is provided with a voltage application section **80** designed to partially stiffen or soften the variable stiffness element **70***d* in each segment. The voltage application section **80** is connected to a controller **30** via a cable, not shown, and functions as a variable stiffness control section that causes the stiffness of a portion of the variable stiffness element **70***d* corresponding to the segment of the voltage application section **80** to be changed, based on a control signal from the controller **30**.

[0043] When a voltage is applied from the voltage application section **80**, the bending stiffness of the variable stiffness element **70***d* is changed in the segment corresponding to the voltage application section **80**. Since the variable stiffness element **70***d* is a continuous member extending over a plurality of segments, even when the stiffness of a portion of the variable stiffness element **70***d* is changed by a voltage applied from the voltage application section **80** of one of the segments, the bending stiffness at the boundary between the segments remains continuous, and is free from discontinuity.

[0044] FIG. **9** is a diagram schematically showing another exemplary configuration of the flexible tube portion **13** according to the second embodiment. In FIG. **9**, a variable stiffness element **70***d*, which is a long continuous member similar to that of FIG. **8**, a voltage application section **80***a* arranged in each of segments **13***a*, **13***b*, **13***c*, **13***d*, and **13***e*, and a voltage application section **80***b* arranged across two continuous (adjacent) segments (for example, segments **13***a* and **13***b*, segments **13***b* and **13***c*, segments **13***c* and **13***d*, and segments **13***d* and **13***e*) are provided. The configuration and the operating principle of the voltage application sections **80***a* and **80***b* are similar to those of the voltage application section **80**. In FIG. **9**, the voltage application sections **80***a* and **80***b* are arranged without interruption in the longitudinal direction of the flexible tube portion **13**. The voltage application sections **80***a* and **80***b* may thus be arranged so as to overlap one another in the longitudinal direction. With such an arrangement, the voltage application sections **80***a* and **80***b* are provided without interruption in the longitudinal direction, and the bending stiffness is free from discontinuity.

[0045] In the present embodiment as well as the first embodiment, it is possible to provide a flexible tube insertion apparatus that eliminates occurrences of V-shaped bending or buckling at a boundary between the segments when an external force is applied, thus improving ease of insertion and ease of operation.

[0046] The arrangement of the variable stiffness elements and the voltage application sections shown in FIGS. **8** and **9** are shown by way of example, and may be any other arrangement, if the stiffness of the variable stiffness elements is continuous in the longitudinal direction of the flexible tube portion **13**.

[0047] Instead of the variable stiffness element **70***d*, a shape-memory alloy (hyperelastic alloy) variable stiffness actuator may be used. In this case, the bending stiffness of the shape-memory alloy (hyperelastic alloy) variable stiffness actuator is changed by heating with a heater, instead of providing the voltage application section **80**.

[0048] While the embodiments of the present invention have been described in terms of the endoscope apparatus **1** comprising the medical endoscope **10**, the present invention is not limited to an endoscope apparatus, and includes any flexible tube insertion apparatus comprising a flexible insertion section.

[0049] Furthermore, a variable stiffness element different from a variable stiffness element that functions as a variable stiffness section (FIGS. **6** and **7**), and a variable stiffness element that functions both as a variable stiffness section and a stiffness connecting portion (FIGS. **8** and **9**) have been mentioned as examples of the stiffness connecting portion, but a member having a stiffness greater than the stiffness of the members forming the flexible tube portion **13** may also be used as the stiffness connecting portion.

[0050] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A flexible tube insertion apparatus, comprising:

a tubular insertion section to be inserted into a subject;

a variable stiffness section that causes change of bending stiffness of the insertion section, in regard to a plurality of continuous segments defined in an axial direction of the insertion section, on a segment-by-segment basis; and

a stiffness connecting portion that is arranged across at least a pair of adjacent segments of the plurality of segments, and causes change of bending stiffness of a portion between the pair of segments in such a manner that the bending stiffness of the portion between the pair of segments is continuous with bending stiffness of the pair of segments, in accordance with change of the bending stiffness of the portion between the pair of segments by the variable stiffness section.

2. The flexible tube insertion apparatus according to claim **1**, wherein the stiffness connecting portion is a member having a stiffness greater than the stiffness of the insertion section.

3. The flexible tube insertion apparatus according to claim **2**, wherein the stiffness connecting portion is a member forming the variable stiffness section.

4. The flexible tube insertion apparatus according to claim **3**, wherein

the variable stiffness section includes a plurality of variable stiffness elements, and

the stiffness connecting portion is configured in such a manner that two of the variable stiffness elements are arranged so as to overlap one another at a boundary between the pair of segments.

5. The flexible tube insertion apparatus according to claim **3**, wherein

the variable stiffness section is a variable stiffness element that continuously causes change of stiffness of two or more adjacent segments of the plurality of segments, and

the stiffness connecting portion is configured in such a manner that the variable stiffness element is arranged across a plurality of boundaries between the segments.

* * * * *